Creativity Skills Applied to Earth Science Education: Examples from K-12 Teachers in a Graduate Creativity Class

Audrey C. Rule

Department of Curriculum & Instruction, 116 Swetman Hall, State University of New York at Oswego, Oswego, New York 13126, arule@oswego.edu

ABSTRACT

In 1950, J. P. Guilford, the President of the American Psychological Association, gave a speech often identified as initiating national interest in creativity in which he asked researchers to find the promise of creativity in our children and to investigate enhancement of the development of the creative personality. Fifty years later, Yager (2000) called for the knowledge accumulated during the ensuing years of inquiry to be applied to science education.

This article briefly explores different aspects of creativity, and then examines K-12 teachers' reactions to exercises applied to earth science concepts in a graduate creativity class. Different types of puzzle activities centering on geoscience content include a quiz game based on Odyssey of the Mind spontaneous problems, and other exercises related to embedded words, transformed clichés, remotely associated word sets, and wordsmithing. Teachers used visualization for an imaginary interview with a geoscientist, along with personal analogy of an earth science feature. As a culminating activity, teachers fashioned a geoscience curriculum material with a given set of items after using Productive Thinking (Schlichter and Palmer, 1993) to generate possible uses for each given material. Ideas for applying the activities to geoscience classes at various grade levels are included.

INTRODUCTION

Yager (2000) presented a six-domain model for science teaching in his article titled "A Vision for What Science Education Should Be Like for the First Twenty-five Years of a New Millennium" that called for the incorporation of more creative thinking into science education. This domain of imaging and creating included visualizing, puzzle solving, generating alternate or unusual uses for objects, combining things in new ways, and producing unusual ideas. Yager lamented (p. 337), "Most science programs view a science program as something to be done to students to help them learn a given body of information. Little formal attention has been given in science programs to the development of students' imaginations and creative thinking... Much research and development has been done on developing students' abilities in this creative domain, but little of this has been purposely incorporated into science programs... Attention to these features approaches real science far more than remembering details or performance skills."

Most geoscience instructors are interested in incorporating creative activities into their teaching, provided these exercises enhance student learning of content. How might this be accomplished and what constitutes a "creative" activity, anyway? I will explore these questions by showing how inservice elementary teachers apply creative thinking exercises to earth science topics during a graduate level course in creativity.

CREATIVITY

There are many research-supported approaches to defining the components of creativity. These include examining mental abilities, creative accomplishments, personality traits, biological traits, biographical traits, observable behaviors, and more-recently explored aspects such as systems of creative activity and motivational aspects of creativity. I will briefly visit different facets of creativity here to give the reader a sense of the many ways creativity manifests itself and therefore the many ways it may be encouraged.

Torrance (1992) identified five major mental abilities, fluency (the ability to produce many ideas), flexibility (the ability to take different approaches to a problem), originality (generating unique ideas), elaboration (the ability to add details to ideas), and resistance to premature closure (the ability to stay open and avoid leaping to conclusions). He also noted several other important creative strengths. Among these are emotional expressiveness, storytelling articulateness, unusual visualization, humor, and fantasy. However, there are other widely recognized mental abilities that contribute to creativity (A good discussion is in Davis and Rimm, 1998, p. 186-8). These include problem finding (detecting difficulties, missing information), problem defining (the ability to identify the "real" problem), visualization (imagining things in the mind's eye), regression (thinking playfully like a child), transformation (changing ideas into new ones) and analogical thinking. In addition, many intellectual abilities support creativity: evaluation, synthesis, analysis, prediction, concentration, and logic.

Bull and Davis (1980), among others (Holland, 1961; Walkup, 1965, Taft and Gilchrist, 1971; Davis, 1975) contended that the best measure of a person's creative potential was his/her history of past creative accomplishments. This supports the argument that involving students in creative school activities may lead to later creative achievements. Bull and Davis classified activities as non-creative, minor creative, and major creative, providing a scale against which to judge a set of accomplishments. Minor creative activities were mostly for personal enjoyment and involved such things as flower arranging, personal home decoration, writing unpublished stories, and producing artwork (unpaid), among others. Major creative activities required some type of public recognition and included publications of poetry or stories, sale of crafts or artwork, patents and commercially available games, and being hired as a performer.

Alternatively, many researchers have focused on the creative personality and the potential for creative works. Davis and Rimm (1998) identified important personality traits: self confidence combined with independence and risk-taking; awareness of own creativity; high energy and adventurousness; preference for complexity and attraction to the mysterious; childlike playfulness and sense of humor; self-reflection; and artistic and aesthetic interests. Torrance (2002), reporting on a 40-year longitudinal study and statistical analysis of factors that

Problem	Example Response	Problem	Example Response
Name something used for mining and what it is used to mine. For example, bulldozers are used to mine clay deposits.	Picks and shovels mine coal.	Name an earth science -related thing that is superior to another and why. For example, quartz is superior to feldspar because it is harder.	An ocean is superior to a lake because it is larger.
	Pickaxes are used to get silver ore.		The Paleozoic is superior to the Precambrian because it is more recent.
	Pumped water mines salt.		Mountains have more volume than hills.
	Steam shovels scoop sand.		Canyon walls are steeper than valley walls.
	Attractive women mine diamonds from rich old men.		Gabbro is darker than felsite.
	Elevators bring zinc ore to the surface.		Large angular rocks have a steeper angle of repose than rounded sand.
	Dynamite blasts marble in a quarry.		Silt grains are larger than clay.
	Solar panels mine sunlight.		Olivine forms earlier than quartz.
	A sifter sorts gravel.		Shield volcanoes are broader than cinder cones.
	A pan is used to get placer gold.		
	Windmills mine electricity.		
	Chisels are used to extract fossils.		
Name things that combine to make an earth science feature. For example, water vapor droplets make clouds.	Volcanoes make an island arc.	Name an earth science feature and one of its parts. For example: A river has a cut bank.	The earth has an inner core.
	Stars make a constellation.		A sand dune has a slip face.
	Cinders make a volcanic cone.		A composite volcano has a crater.
	Sand grains make a dune.		A continent has a continental shelf.
	Planets, moons, the sun and asteroids make the solar system.		The moon has a phase called new moon.
	High winds make a tornado.		Caves have stalactites.
	Waves make an ocean surface.		A mountain has a summit.
	Connected streams make a drainage basin.		A topographic map has a contour interval.
	Sand and gravel makes a conglomerate.		A dinosaur fossil has a vertebra.
Name an earth science tool or instrument and its use or purpose. For example, a compass is used to locate magnetic north.	A weathervane shows wind direction.	Name an earth science interface and what it separates. For example, the Mojorovicic Discontinuity separates the crust from the mantle.	Tropic of Cancer and the Tropic of Capricorn separate the tropics from the mid-latitudes.
	Pencils record data.		The ocean surface separates water from air.
	Flashlight lights a cave.		Continents separate oceans.
	Seismograph record earthquakes.		An erosion surface separates some rock layers.
	Barometer measures air pressure.		Lava tube walls separate cool from hot lava.
	A brush cleans fossils.		Melt water separates a glacier from bedrock.
	A balance is used to measure mass.		The K-T boundary separates dinosaurs from their extinction.
	Telescopes allow us to see space objects.		
	A Brunton compass measures strike and dip.		

Table 1. Odyssey of the Mind-type spontaneous problems and example responses.

foster or inhibit creativity over time, found that six personality factors were most important in predicting creative output: 1) loving one's work; 2) recognizing one's greatest strengths; 3) playing one's own game; 4) not being well rounded; 5) loving the work you do; and 6) learning the skills of interdependence and shared creativity. The study of implicit theories of creativity (folk theories or individuals' personal definitions of creativity) allows social validation of experts' theories. Teachers and parents asked to characterize creative children agreed upon these descriptors: adventurous, alert, ambitious, artistic, capable, curious, dreamy, energetic, enthusiastic, and imaginative (Runco, Johnson, & Bear, 1993).

Biological traits are also active in determining creativity. Farley (2001) identified a "Type T" personality that is associated with a specific brain biochemistry owing to a genetic "long form of the D4 receptor allele that contains seven repeat sequences in exon III, than a shorter version of the gene that contains only four

repeats" (Tingley, 1996). This personality is motivated by risk, novelty, complexity, low structure, and intensity (Note that "risk-taking" was listed as the most important personality trait in the paragraph above). Two large studies, one occurring at the National Institutes of Health (Benjamin, et al., 1996) and the other in Israel (Ebstein, et al., 1996), have confirmed the relationship using blood assays.

Biographical traits recognized as associated with creative producers, include a background of creative interests (crafts, building projects, unusual collections, theatrical performances, and scientific inventions), imaginary play companions (Somers and Yawkey, 1984; Schaefer, 1969) and a pattern of parental support that includes early years of home instruction in a particular area of interest followed by expert tutoring (Feldman, 1993; Feldman and Goldsmith, 2000). Additionally, observable behaviors of creative individuals are: a voluntary interest, initiation or love of a subject; work that goes above and beyond assignments; perfectionism; moral sensitivity; sense of humor; drive to learn; and consultation of experts (Renzulli, 1977; 1978; Renzulli et al., 2002).

Other recent models of creativity focus on cultural aspects and the interrelationship between individual processes and social processes. One model, flow theory (based on Koch's work in 1956 and further developed by Csikszentmihalyi, 1990; and Moneta & Csikszentmihalyi, 1999), uses an O-S-O-R framework in which the first "O" represents the organism (or person) actively seeking and choosing the stimulus ("S"), then filtering it (the second "O") and responding ("R"). There are four outcomes of the model: 1) when skills and challenges are both low, the person experiences apathy; 2) when challenges exceed skills, anxiety occurs; 3) when skills are greater than challenges, the person becomes bored; 4) however, when challenges and skills are both high, the person experiences flow in consciousness and the overall quality of the experience is highest. To bring about "flow", one needs to focus attention on a narrow range of content. Csikszentmihalyi, Rathunde, and Whalen (1993) found that the percentage of time teenagers experienced flow during their talent-related activities predicted whether these students were still involved in these activities years later. Flow was a better predictor of talent engagement than all other variables including grades, teacher ratings, highest talent level reached, and subjective commitment.

Finally, a hotly contested aspect of creativity research is whether creative thinking skills are content-and task- specific or can be generalized to many content areas. There is evidence and argument for both sides of the issue (Baer, 1994 a, 1994 b, 1994c; Cramond, 1994; Kogan, 1994; and Plucker, 1998). This paper applies several different sets of creative thinking skills to earth science content, but these same skills are easily applied to other curriculum areas, supporting the content general point of view. Future work may identify exercises for developing earth-science specific creative thinking skills. Now that many different manifestations of creativity have been considered, I will examine how some of these may be applied to earth science education. In the following sections, I will present the products and insights of primary and secondary teachers enrolled in a graduate course in creativity who participated in puzzle activities, visualization, and a curriculum material "invention" related to earth science, along with ideas for applying the exercises to geoscience classes.

PUZZLE ACTIVITIES

Odyssey of the Mind - Odyssey of the Mind is an international educational program that provides kindergarten through college students with a variety of creative problem solving opportunities. Students work as teams on long-term problems such as skits or inventions and on shorter spontaneous problems presented in a sort of quiz-show format during local, regional, national and international competitions. There are many books of problem activities (e.g. Micklus, 1992; 1996; Micklus and Micklus, 1997). Teachers in the graduate creativity class tried several of the spontaneous problems, and then composed others that were more directly related to earth science topics. These are presented in Table 1 along with example responses. An important outcome of these exercises is the large number of connections that are made between different geoscience topics through new perspectives of categorizing objects or events.

To implement these activities, divide the class into equal-sized teams of about 5 to 8 students. The performing team members sit on chairs at the front of the room. They are presented with the problem, given one minute to think silently of ideas or ask questions of the instructor about the problem, and two minutes to respond. Team members should respond in order, one at a time, as quickly as possible. Although Odyssey of the Mind rules do not allow passing or assistance from teammates, this format may be modified for classroom use. Perhaps passing might be permitted with a scoring penalty. Put one of the non-performing teams in charge of keeping time, while another team serves as scorekeeper-judges. Each common response receives one point, but a highly creative response that receives laughter, involves a pun, or is unusual, scores three points. This activity is a lively way to review material when a unit has been completed. Questions may be given in advance for all students to research, then drawn out of a hat for each team during the game.

Several teachers implemented the above activities with their own students with favorable results. A ninth grade earth science teacher modified the activity, allowing teams to research responses for the complete set of questions before the competition began, with questions being drawn randomly during the game. Students were highly excited during the research period and the game, with all parties finding this to be an effective format for review of content information. Another teacher's class of second grade students enjoyed naming different water or landforms (e.g. river, stream, lake, ocean, beach, crashing waves, mountains, plain, hills, cliff, cave), items on a map (e.g. legend, compass, grid, roads, forest, houses, city), and things in the sky (e.g. sun, clouds, constellations, lightning, birds, planes, spaceships, moon, planets).

Imaging Activity - Before a child learns to think in words, he/she uses images. Images are the language of dreams and the persistent thought medium for many adults. Some problems are best solved through images rather than words, particularly those involving shapes, patterns, or spatial relationships. Imagery is useful to creativity because it provides uncensored access to ideas

Gastro! No, my dear; it is the study of celestial bodies, not intestinal ones!
This ol' array turns like a posy stem of colored petals chasing the center yellow sun.
It's unbelievable how hot this star's surface can get: thousands of degrees Celsius!
The best are the brightest when you look in the sky, with Sirius topping the list.
This planet is near the sun for warmth, but just the right distance away for life.
An observer of this phenomenon is in danger of blindness if he/she clips everyday sunglass lenses over the eyes.
The cows moo nightly at this luminous natural satellite of Earth before attempting to jump over it.
This ringed gas giant makes a turn every ten hours.
Even US spacecraft were not the first to land on this planet: the Soviet probe Venera 7 went there in 1970.
The distortion of space around this hub lacks support to prevent the whole mass of nearby objects from eventually being engulfed.

Table 2. Embedded word puzzles related to astronomy. The embedded word answers are underlined.

from the subconscious. There are three main types of imagery (McKim, 1980). Perceptual imagery is one's sensory experience of the physical world that is recorded in the brain. Mental imagery draws upon this store of knowledge to construct pictures in the mind's eye. Finally, graphic imagery includes sketched or drawn images that are used in the thinking or communication process. Applying these ideas to geoscience, noticing forms and relationships between features such as rock or cloud formations is antecedent to constructing mental images, which are then used to produce weather maps or structural geology figures.

Imagery is useful in creative problem solving for many reasons (Bagley, 1987). Imagery does not depend upon verbal thinking, which occurs at a slow pace - the speed of speech. It is faster and images can be speeded through more quickly than clock-measured time. There is no limit to the number of mental manipulations that can be performed on images, such as changing orientation, speeding or slowing them, reversing, or changing different components.

Teachers participated in an imagery exercise for the purpose of generating more geoscience-related questions for an Odyssey of the Mind-type quiz game. This exercise was based on an exercise in Bagley's book Using Imagery in Creative Problem Solving (1987). In the class activity, participants relaxed and imagined that they were going on a short trip to visit a geoscientist of choice. Each teacher mentally visited this person at his/her place of work and discussed ideas for new geoscience-related questions for the game. After about five minutes of visualizing the meetings, teachers turned their focus back to the present classroom and reported their new ideas.

One teacher met with Neil Armstrong who recalled his experiences of weightlessness in space such as toothpaste not staying on a toothbrush. Her quiz-game question was, "Name events that might take place in zero gravity" (e. g., milk would float away; a person could sleep in any position). Several teachers interviewed TV weather personalities. One of the resulting ideas was, "Name factors that affect the weather " (e. g., wind speed, elevation, relative humidity). An imagined discussion with a knowledgeable co-worker resulted in this idea: "Name a natural disaster and one of its causes" (e. g., earthquake damage because of poor construction, landslide owing to wet clay layer). A conversation with an oceanographer friend brought this question: "Name things that can be found on the ocean floor" (e. g., mid-ocean ridge, black smoker vents). Other teachers reported conversations with Galileo and Stephen Hawkings. An interesting aspect of this exercise was the surprise participants expressed in being able to generate useful questions through this activity, because previous to the visualizations, no one could suggest another possible game question.

Visualization activities can be used to review earth science content. Remember that images in the mind's eye have their source in previous experience. Prime the store of knowledge with earth science videos, photographs, or magazine articles about earth science topics. Then ask students to relax, close their eyes, and view a situation. Some ideas for visualization include: imagining the journey of a quartz crystal in the rock cycle or a water drop in the water cycle; taking an imaginary trip through the throat of a volcano, along the path of seismic waves, or to the surface of the moon; or taking a geoscience process such as metamorphism or development of a hurricane and seeing it in slow motion.

Embedded Word Puzzles - Guilford, the cognitive psychologist who devised the Structure of the Intellect model of human thought analyzed as content, operation, and product (Guilford, 1967), determined through factor analysis the thinking operation and product category most important to creativity (1986). These are the thinking operation of divergent production, the ability to generate many alternate items that meet the thinker's need or solve the problem, and the product category of transformation, which refers to any rearrangement or change in an item of information. To practice divergent production of transformations, teachers were asked to make several embedded word puzzles (examples shown in Table 2). An embedded word puzzle is a statement or question that contains a hidden answer embedded as contiguous letters in its words. The solver must recognize the hidden word or words by rearranging the spacing of the original sentence, thereby isolating the words. In Table 2, the embedded words are shown by underline. This activity was made more content-related by requiring the teachers to include an earth science fact in each puzzle.

The puzzles in Table 2 can best be used as a model for students to emulate in creating their own word puzzles. The highest levels of learning (Anderson and Krathwohl, 2001) occur as students put together their own ideas (synthesis) and then evaluate their products (evaluation). If students first devise puzzles and try them with peers, they will discover errors and begin to develop valuable self-evaluation skills.

High Vocabulary Puzzles - Intelligence and creativity are different, yet related cognitive abilities (Barron, 1969; MacKinnon, 1961, 1978; Getzels and Jackson, 1962; and Wallack and Kogan, 1965). Generally, creativity increases with intelligence until a threshold I.Q. of about

High Vocabulary Puzzle	Common Saying
Preeminent companions to maidens are exorbitant compactions of carbon.	Diamonds are a girl's best friend
As transparent as a geometrically configured mineral specimen without coloration or opacity.	Crystal clear
An adamantine crystalline jewel is a woman's finest familiar.	Diamonds are a girl's best friend
Indurate as an aggregate of minerals.	Hard as a rock
Restrained interjacently by a consolidated mineral mass and a firmly fused location.	Caught between a rock and a hard place
A revolving cluster of minerals retains nary a bryophyte.	A rolling stone gathers no moss
Withdraw from currently attempted accomplishments to return to excavations of a common seasoning and preservative.	Back to the salt mines
A solid agglomeration of minerals' launch into the distance.	A stone's throw away
Hesitating until the microscopic aluminosilicates descend from atmospheric suspension.	Waiting for the dust to settle
From beneath what petrologic manifestation did you emerge?	What rock did you crawl out from under?

Table 3. High vocabulary word puzzles related to rocks and minerals.

120 is reached (an I. Q. of 100 being the mean of the population and 15 representing one standard deviation). After that point, there is no discernable relationship between intelligence and creativity (MacKinnon, 1978). This does not mean that highly intelligent people cannot perform creatively; it merely shows that they are not necessarily disposed to do so. Perhaps they prefer to solve their problems through intellectual means. Creativity depends upon personality and motivational characteristics that have been repeatedly confirmed by research (Davis, 1975; Torrance, 1962, 1965, 1977, 1988; Sternberg and Lubart, 1993). These include independence, tolerance of ambiguity, risk-taking, perseverance, confidence, playfulness, sense of humor, and willingness to change and grow.

In the puzzles presented here, teachers combined humor and playfulness with a recognized marker for intelligence, extensive vocabulary, by transforming common sayings into synonymous phrases. They used several Internet sites that listed common sayings and clichés to find earth science-related phrases. Teachers enjoyed creating their own puzzles and deciphering those of classmates. As in the embedded word puzzle above, these puzzles should be used as springboards for student work. Examples are shown in Table 3.

Remote Associates

Mednick (1962) defined creative thinking as the "forming of associative elements into new combinations which meet specific requirements." He developed a creativity test called the Remote Associates Test (1967) that presented the student with three words somehow

Three Words that are Remotely Associated	Associated Word
Fast, electric, bug	Lightning
Spout, mineral, table	Water
Castle, brain, thunder	Storm
Cooker, barometric, blood	Pressure
Baby, rain, cap	Shower
Parade, bow, coat	Rain
Dry, caps, cream	Ice
Mill, north, instrument	Wind
Warm, ocean, yard	Front
College, Celsius, burn	Degree
Channel, vane, report	Weather
Nine, cumulus, judgment	Cloud
Rock, life, water	Cycle
White, shoe, flake	Snow

Table 4. Remote associates puzzles related to meteorology.

associated with a fourth word, and asked the student to produce the fourth word. An example is "lick", "sprinkle" and "mines". The correct response is "salt" because this word is associated with each of the three words by the following common phrases: saltlick; sprinkle salt on food or ice; and back to the salt mines. In the process of solving problems of this type, the student searches for all possible known associations for each of the three words (divergent production), then converges on the idea all three have in common. Teachers enjoyed producing the remote associate puzzles shown in Table 4, and found that this process allowed them to review earth science concepts as they searched for different associated ideas. Can your students devise new sets of words remotely associated with terms related to a different geoscience topic area?

Wordsmithing - A sense of humor is one of the characteristics of a creative person. Humor allows a problem or assignment to be approached in a fresh, playful, childlike manner. Humor results when ideas from different domains are suddenly brought together in a new and surprising way. This "twist" is really a type of transformation in the form of a pun, satire, farce, or unexpected result.

Teachers produced word transformations similar to the Washington Post Newspaper's Style Invitational, which asked readers to take any word from the dictionary, alter it by adding, subtracting, or changing one letter, and supply a new definition. Here, teachers were asked to choose an earth science word, alter it, and write a new definition that included an earth science fact. For example, one teacher took the word "constellation" and changed it to "monstellation", saying this designated a very large star picture like Hydra the sea serpent, a constellation that covers 100 degrees in length. Table 5 shows a variety of transformations made with the term "volcano". Can your students choose another earth science word such as plateau, equator, weather, or igneous and transform it to make new terms?

Volcano (n.), An opening in the earth's crust through which molten lava, ash, and gases are ejected.
Vilcano (n.), an evil eruption that takes lives, such as the 1991 massive eruption of Mount Pinatubo in the Philippines that trapped people under collapsing roofs covered with heavy rain-soaked ash.
Volcan't (n.), A volcano well on its way from inactive to extinct, being removed from the geologic conditions that gave rise to it.
Velcano (n.), A cinder cone, such as the one from the 1944 eruption in Paricutin, Mexico, that is painted on black velvet.
Volcanon (n.), The throat of a volcano from which bombs and other projectiles are emitted.
Volpano (n.), an intense burning sensation experienced by early humans who left their footprints in the volcanic ash of the Roccamonfina volcanic complex in southern Italy.
Volchano (n.), a string of islands created by a hot spot such as the Hawaiian Islands.
Volycano (n.), a mountain sport in which nearby vents attempt to smother each other by throwing ejecta.
Volcrano (n.), a volcano who sticks its neck out, like the one at Devil's Tower, Wyoming.
Evolcano (n.), an old, extinct volcano being subducted into a trench, thereby feeding a new series of volcanoes.
Volecano (n.), a mountain made out of a vole hill, such as worrying about your home being destroyed by a lahar when you live in Kansas.

Table 5. Wordsmithing with the term volcano.

Gold plastic ice cream pint lid
Spherical gold metallic ornament
Half-sheet of clear plastic canvas
Two small white paper cups
Green pompom
Thin black cord
Green laundry detergent bottle lid
Cardboard egg carton side piece and two eggcups
Strand of pearly blue beads
Plastic bubble wrap
Printed cloth ribbon
Two tongue depressors
Twelve pistachio shell halves
Six white plastic water bottle caps
A silk rose
Four strips of black mat board

Table 7. Junk materials given to each teacher for creation of the curriculum material.

A teacher from my graduate class tried wordsmithing with his ninth grade students. Examples of their work include the following definitions for altered forms of "sediments."

Criteria	Points Scored		
	Met	Board-erline	Not Met
Pre-project work. List of ten ideas that were contributed to an in-class discussion of possible projects.	1	¾ or ½ or ¼	0
Pre-project work. Chart of at least 5 categories of use for one given material and at least 25 different ideas distributed among the categories for in-class discussion.	1	¾ or ½ or ¼	0
All materials provided are used (scraps may be discarded) with no more than three other materials.	1	¾ or ½ or ¼	0
Clear and logical verbal explanation in class of how the material will be used.	2	1½ or 1 or ½	0
State or national science standards addressed by the project.	1	¾ or ½ or ¼	0
Paragraph of how the project will be used in lessons to elementary students.	1	¾ or ½ or ¼	0
Include diagram that shows how all the different given materials and any extra materials were incorporated	1	¾ or ½ or ¼	0
Science content of project is correct.	1	¾ or ½ or ¼	0
Creativity displayed through unusual or clever use of materials, aesthetic appeal of project, or humor.	1	¾ or ½ or ¼	0
Total Points of 10 Possible			

Table 6. Rubric for grading curriculum material projects.

Mediments: A type of rock that is used in medical treatment (e.g. clay mudpacks).
Lediments: Rock that can be smelted for its lead content.

PERSONIFICATION

I instructed teachers to choose an earth science feature and to "become" the item, trying to sense its physical parts and surroundings with all the senses, and its actions, reactions and imagined humanlike motivations. Teachers asked themselves, "How would I feel if I were ...?" or "What would this object say to me if it could think and talk?" This activity is drawn from the Synectics Research Program described by Gordon (1961) that conducted research into creativity using problems from consultation with industry. The exercise of becoming an item related to the problem is called personal analogy. This type of metaphor has the effect of intellectual illumination combined with emotional excitement. Participants creating the personal analogies became keenly aware of the limitations of their knowledge about

Given Object	Category	Ideas for how object could be used
Gold plastic lid from ice cream pint	Space	Asteroids, sun, planets, moon, stars
	Things found on the ground	Earthquake cracks, base for fossil, a layer of the earth, cut to make mountains or bones
	Ocean	Cut into sand particles, make plants, shells, coral, fish
Green plastic laundry detergent lid	Transportation	Make into a boat, rocket, wheel, submarine, bulldozer
	Body part	Torso, face, leg, nose, head
	Structure	Building, house, island, tent, table
Cardboard egg carton piece	Viewing items	Binoculars, goggles, microscope parts, magnifying glass
	Landform features	Cave outline, volcanic cone, crate in moon, glacier, coral reef
	Tool	Shovel, scoop, sifter, wheelbarrow
Dark blue pearly bead strand	Precipitation	Raindrops, snow, sleet, hail, dew
	Body of water	Stream, river, ocean, lake, bay
	Solar system	Planet, moon, asteroid, star, satellite
Clear plastic bubble wrap	Skey items	Color dots for constellations, roofs, rocks, ice chunks, Saturn rings, jet streams
	Clouds	Different types of clouds
	Pockets of elements	Periodic table, ask from volcano, fossils, air bubbles
Red / maroon printed cloth ribbon	Meteorology	Tornado, cold front, lightning, rainbow, mudslide
	Geography	Mountain, rock layer, delta, river system, rift
	Plate tectonics	Ring of Fire, layers of Earth's crust, mid-ocean ridge, island chain
Tongue Depressors	Nature	Tree trunk, plant stem, sand, stalagmite
	Nautical	Underwater plants, boat bottom, sand, fish
	House part	Roof, fence, siding, sidewalk, shingles
Silk rose	Clothing	Skirt, top, dress, pants
	Nature	Raindrops, waves, stars, lava, clouds
	Filter material	Bricks, layers, colored rock, float

Table 8. Productive thinking of possible uses for the given materials.

the features they were exploring, and were therefore motivated to research more information. Here are two excerpts from personal analogies.

"I was once a jagged towering rock formation standing in the Sonoran Desert thousands of years ago. With the passing years I have become somewhat a shadow of my former self but with curves and smooth lines any rock would envy. I have the wind and the sand to thank for my "face lift." The wind picked up grains of sand as it traveled over the desert surface, scrubbing and polishing my face, reshaping me, transforming me, as bit by bit the sand ground away my surfaces... This erosion has created holes in my walls, and I have been reborn as a beautiful rock arch."

" I am a dormant volcano awakening from a long rest with other snow-capped mountains. I feel pressure and warming from below. I shift uncomfortably. I feel hot and melting snow drip down my face. My sides feel soggy and swollen with mud. The pressure increases as hot magma moves into my stomach. Steam escapes through my ears and nose. I smell sulfur. The streams on my sides begin to boil. Suddenly, magma moves up my throat and hot lava spills from my mouth. I belch ash. I vomit great lava flows, breathe fire, and sneeze, causing a landslide of mud and debris. The forests on my flanks fall and burn. I shift uncomfortably again. More lava flows out. I feel relieved and rest. After a while pressure builds again..."

An interesting assignment might be to ask students to write scripts and perform personal analogy skits of earth science features related to the class curriculum. Set requirements of performance time limits and the number of science facts that must be presented through each skit.

CURRICULUM MATERIAL PROJECT

Teachers were each provided an identical bag of materials from which they were to invent a curriculum material for teaching an earth science topic related to the state or national science curriculum for elementary students. Table 6 shows the rubric for grading the projects. They were instructed to incorporate each given item in the project, with up to three other standard items of each teacher's choice such as poster board, paper, paint, markers, or crayons being allowed. The materials of each set are listed in Table 7. This assignment required creative thinking to transform the collection of junk items into a recognizable and useful poster, mobile, or model. Teachers generated the following ideas for possible elementary projects: ocean-bottom or reef environment; parts of a volcano; constellations, planets, or other astronomical bodies; cloud types; periodic table; layers

Figure 1. Galileo's telescope with view of stars, planets, and Milky Way at base.

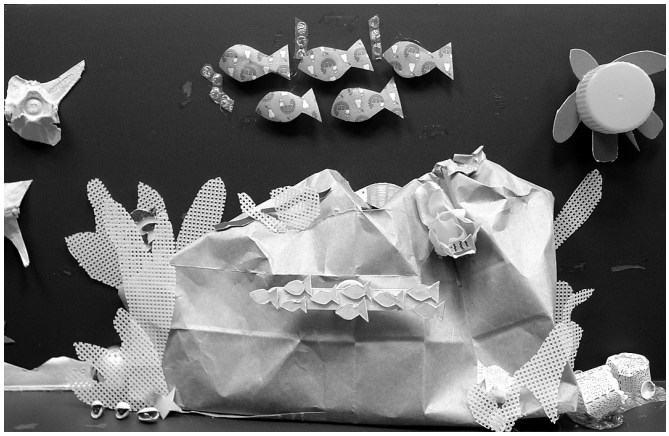

Figure 2. Underwater fossil life scene.

of the earth; cave formations; water cycle; rock cycle; fossil life including dinosaurs; earthquakes; mining; glaciers; weathering; landforms such as rivers, sand dunes; the four seasons; Antarctica; acid rain effects; global warming; energy from the sun; maps; rock classifications; ocean currents; and natural hazards.

Productive Thinking - Teachers used the Productive Thinking skill from the Talents Unlimited thinking skills (Schlichter and Palmer, 1993) to devise ideas for the different given materials. The key words for this talent are: 1) many; 2) different; 3) unusual; and 4) add details, which correspond to the creative thinking skills of fluency, flexibility, originality, and elaboration. 1) For each given object, they thought of many ways it might be used. 2) Then, they looked at the list of ideas, and categorized them. For each different category, they tried to generate additional ideas. 3) Teachers also attempted to produce unusual ideas. 4) Finally, they added details to the generated ideas to improve them. Table 8 shows some of the generated ideas for example given items.

The productive thinking activity was an important process in creating the curriculum materials. Almost all the teachers reported feeling overwhelmed with the assignment before participating in the productive

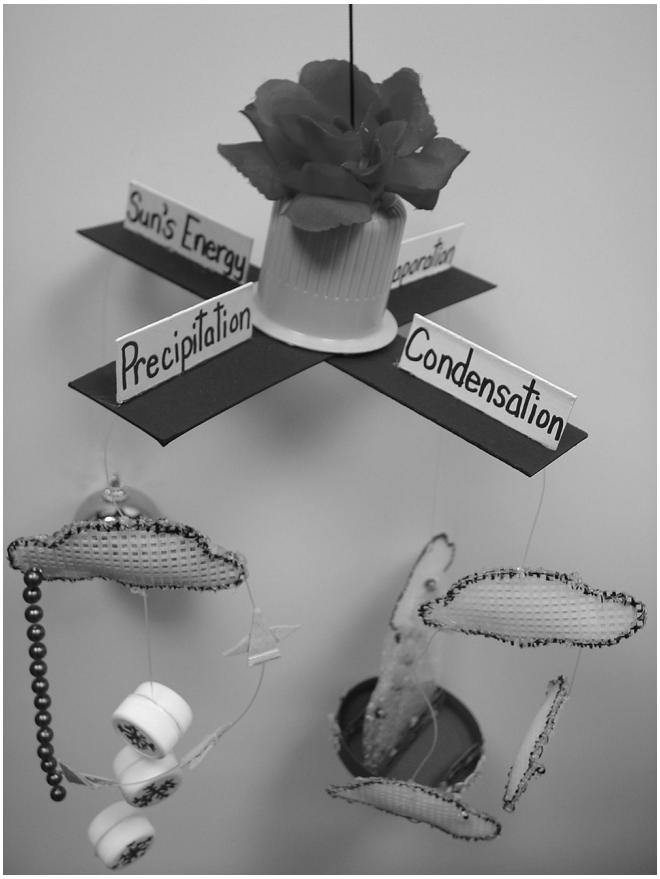

Figure 3. The water cycle mobile.

Figure 4. A black hole from a poster of the life cycle of a star.

Figure 5. Model of the formation of a glacier.

Figure 6. The super nova from the life cycle of a star.

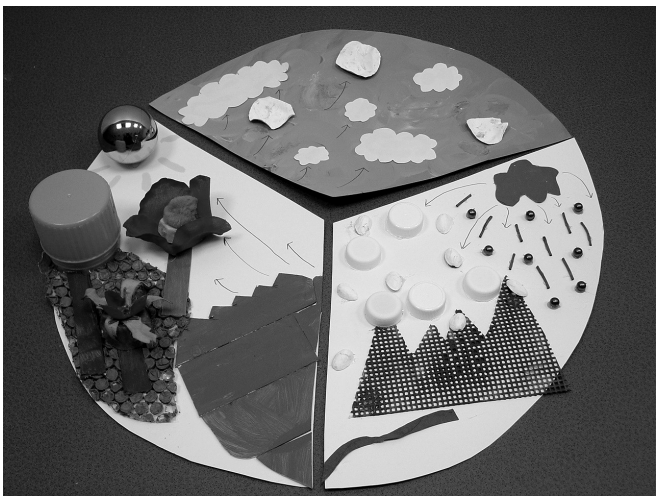

Figure 7. A poster representation of the water cycle.

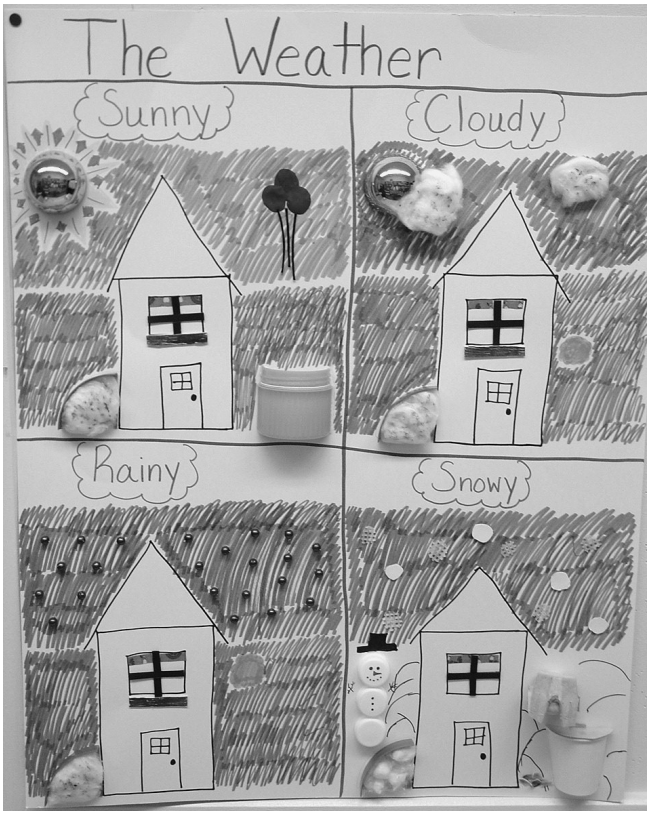

Figure 8. Poster for teaching preschoolers common weather conditions.

Figure 9. Model depicting the formation of lake effect snow.

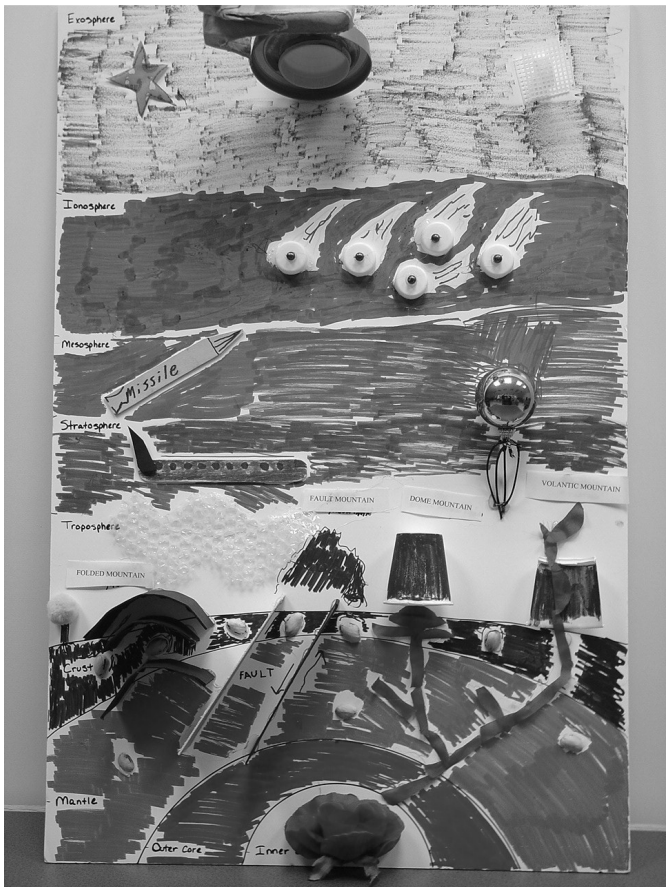

Figure 10. Poster of the layers of the earth and its atmosphere.

thinking exercises. But after ideas were generated, teachers reported great motivation and excitement in working on the assignment. After productive thinking had been performed with all items, teachers decided their projects and planned their completion.

Teachers chose a variety of earth science topics for their elementary curriculum projects: Galileo's telescope, the life of a star, the formation of the earth, parts of a volcano, the layers of the earth and stratosphere, fossil marine life, the water cycle, the origin of lake effect snow, formation of glaciers, and weather charts. Many of the completed projects are shown in Figures 1 through 10. Several materials were used in interesting and clever ways. The plastic laundry detergent lid was used as part of the base of the telescope (Figure 1), as a turtle shell in the fossil life scene (Figure 2), as the hub of the water cycle mobile (Figure 3), as a black hole in a poster depicting the life cycle of a star (Figure 4), and as part of a space station (Figure 10). The plastic bubble wrap was painted white to become the surface of a glacier (Figure 5), used as strips of fish bubbles (Figure 2), represented the Milky Way at the bottom of the sky viewed by Galileo's telescope (Figure 1), was cut apart to depict the exploding super nova (Figure 6), and became the relatively warm surface of a lake (Figure 9). Although many teachers found it difficult to break away from the idea of the gold ornament as the sun (e.g., Figures 3, 5, 7, 8), some solved this problem by using the ornament as padding beneath a surface. The ornament was employed as filler in the underwater scene (Figure 2) and beneath the snow surface in the lake effect snow model (Figure 9). Other creative uses of the ornament were as a pivot point for the telescope (Figure 1) and as a weather balloon in the model of the layers of the earth and atmosphere (Figure 10).

Teachers described their creative process in making the curriculum materials. The maker of Galileo's telescope (Figure 1) reported," When I attempt to do something creative, I have a hard time picturing it in my mind... When I thought of making the telescope, I had to play with the materials, draw a diagram of what it would look like, and label how all the materials would be used. After drawing and labeling the diagram, I realized that if I use this technique to help develop ideas, that I can use various materials to create projects." The teacher who made the layers of the earth poster (Figure 10) explained, "One block that I overcame was not knowing the earth science curriculum... I solved this by checking out a textbook from the library and studying the information." Another teacher discussed her fear of making a mistake: "I am the type of person who strives for perfection and it is difficult for me to just start on something when I don't have a clear vision of what the outcome will be."

Teachers reported that they thoroughly enjoyed the project because the creative challenges made the feeling of accomplishment greater. Several teachers had already involved their classes with generating ideas for the projects they made and reported that students had expressed the desire to make their own projects with a set of given materials. An important culmination of the project work was displaying the curriculum materials and giving brief verbal presentations about them. This sharing allowed the teachers to notice and appreciate the many different interpretations of the given materials.

Instructors at any grade level can involve their students in a similar project. Consider asking students to work in groups and specifying a list of allowed materials rather than providing them. One possibility is to ask students to create an earth science object using newspaper and masking tape only. However, the teachers in the creativity class enjoyed thinking of alternate uses for the junk items and marveling at how their peers cleverly handled the materials in different ways. A third grade teacher applied a similar project to her class by dividing her students into groups and giving each an identical set of "junk" items. Students loved the activity and produced completed projects in less than an hour. Another idea is to ask each student or pair of students (depending upon class size) to bring in a set of identical junk items (clothespins, Styrofoam pellets, bottle caps, pieces of ribbon or cord, etc.) equal to the number of groups in the class, which are then sorted into identical sets and distributed to students.

The teachers in the creativity class described here enjoyed creating the puzzles and curriculum materials. When they were working on creative activities for their grade-level curriculum, many reported experiencing "flow" as described earlier in this paper. At those times, the classroom hummed with quiet discussions of teachers generating ideas with others; everyone was fully engaged and challenged at the appropriate skill

level. Many have already implemented these activities with their elementary students and have experienced favorable results. Try some of them with your students. Most of the ideas presented here are adaptable to elementary, secondary, and college classes.

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